Percutaneous Microwave Tissue Coagulation in Liver Biopsy : Experimental and Clinical Studies

Arch Jpn Chir 55(3), 381～392, Mai, 1986

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Percutaneous Microwave Tissue Coagulation in Liver Biopsy: Experimental and Clinical Studies

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Received for Publication, Feb. 14, 1986.

Introduction

The microwave tissue coagulator is an excellent device useful for tissue coagulation and hemostasis[17]. Microwave surgery using this device has been applied clinically in hepatectomy in our department since 1980[18]. This technique, which offers a decided advantage over the conventional methods, has already been applied in several clinical fields such as abdominal surgery including liver surgery[15,19,20,21] and endoscopic surgery[5,11,22] in Japan.

We recently devised a new method using this microwave coagulator, which was expected to be useful for the prevention of bleeding and malignant seeding in the needle tract after liver biopsy. This paper delineates the experimental data obtained by this method and our preliminary experience with 44 patients with liver diseases.

Materials and Methods

Microwave tissue coagulator and "percutaneous needle-electrode"

The microwave tissue coagulator used was a MICROTAZE, model HS-15M (Heiwa Electronic Ind., Ltd.), which was detailed earlier[17,21] (Figure 1). This coagulator was used in combination with a specially designed needle-like electrode that permits percutaneous microwave tissue coagulation. We called it "percutaneous needle-electrode" (needle-electrode). The most eminent characteristics of the needle-electrode is that an antenna is attached to the tip of the

Key words: Liver biopsy, Complication, Treatment, Microwave, Microwave tissue coagulator.
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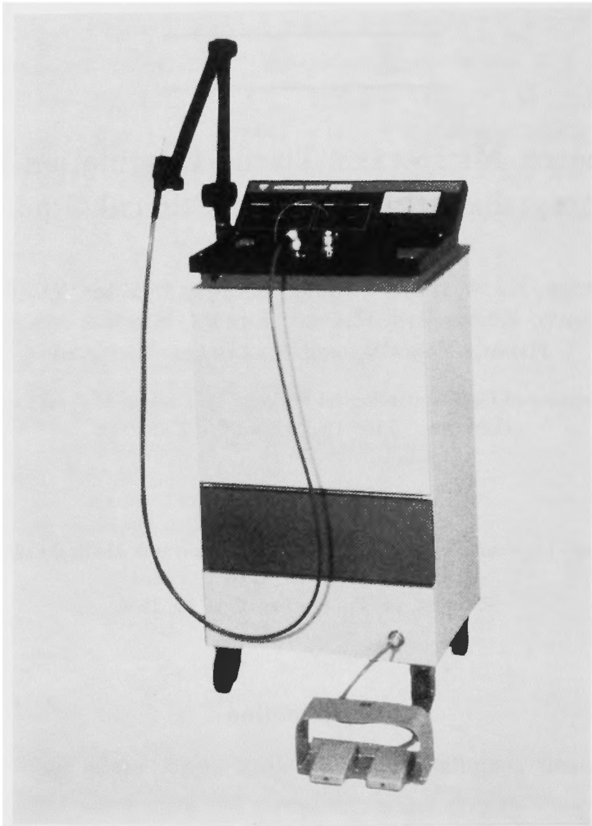

Figure 1. Microwave tissue coagulater (Heiwa Electronic Ind. Ltd.).

stainless steel needle tube which acts as a coaxial cable. There are three types of electrodes, which are different in diameter (2.4 mm, 2.0 mm, 1.2 mm). Each of them can be connected to the microwave tissue coagulator (Figure 2).

Experimental study

In the experimental study which was undertaken to gain a clear picture of the characteristics of the needle-electrode, three adult mongrel dogs weighing 10–14 kg were used. Under pentobarbital anesthesia, laparotomy was done and the needle-electrode was inserted into the liver directly. The needle-electrode was composed of a stainless steel needle tube of 2.4 mm in diameter and 140 mm in length and an antenna of 0.9 mm in diameter and 10 mm in length.

The power of the needle-electrode was examined under different conditions in terms of irradiation output, irradiation time, and insertion depth as shown in Table 1. It was inserted obliquely to the liver surface and the tip of it was oriented towards the hilus of the liver (Figure 3).

One of the three dogs was sacrificed on day 0 (immediately after operation), another on day 7 (7th postoperative day), and the last one on day 21 by intravenous injection of formalin. The liver was taken out surgically without unnecessary delay and cut along the axis of the needle tract. The coagulated area and the repair process were examined macroscopically and histo-

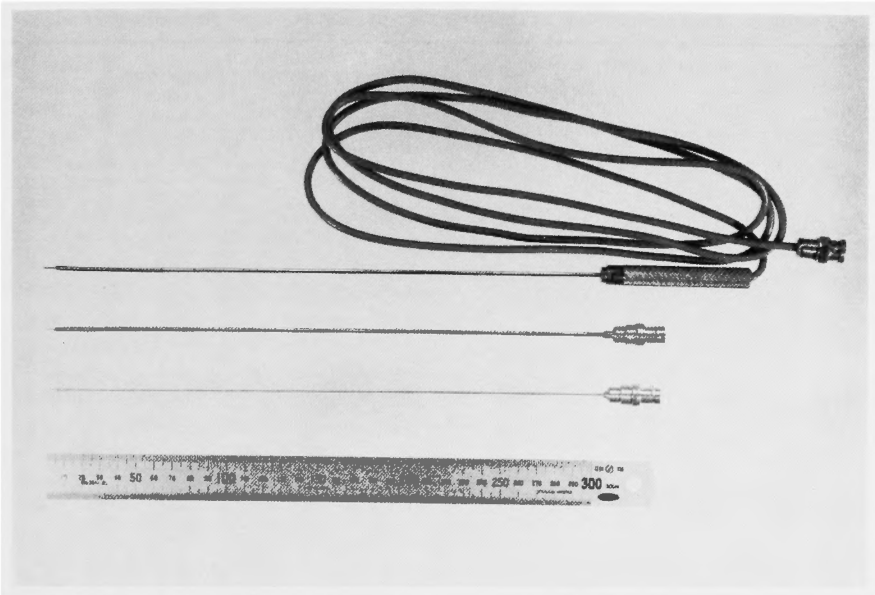

Figure 2. Specially designed needle electrode called "percutaneous needle-electrode" Three different types in diameter (2.4 mm, 2.0 mm, 1.2 mm) are shown. A monopolar antenna is attached to the tip of the stainless steel needle tube which acts as a coaxial cable.

logically. The animal sacrificed on day 7 and the one sacrificed on day 21 were treated with antibiotics on day 1–day 3. In the dog sacrificed on day 0, the ultrasonographic observations were compared with the macroscopic findings on the liver removed later.

Clinical study

At the clinical level, a combination of percutaneous microwave coagulation and liver biopsy

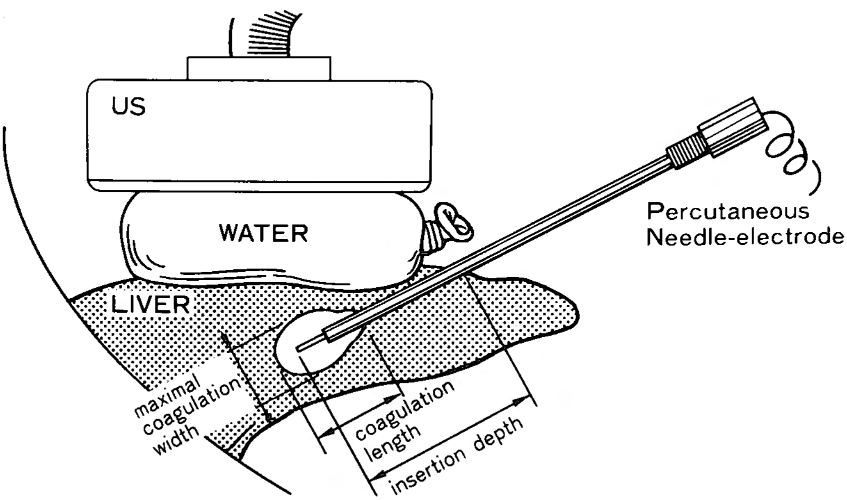

Figure 3. Illustration of the experimental study which was undertaken to gain a picture of the characteristics of the needle electrode.

Table 1. Experimental data of the characteristics and power of the needle-electrode.

Irradiation out put (watt)	irradiation time (sec.)	Postoperative day (day)	Coagulation length × Maximal coagulation width (mm)	Congestion (mm)	Coagulation depth (mm)
30	15	0	14.0× 6.0	2.0	20.0
		7	15.0× 5.5	—	15.5
		21	10.0× 3.0	—	15.5
30	30	0	15.0× 6.0	2.0	20.0
		7	24.0× 9.0	—	24.0
		21	15.0× 4.0	—	21.0
30	60	0	23.0× 7.0	2.5	23.0
		7	20.1×11.5	—	20.0
		21	00.0× 4.0	—	16.0
30	15	0	12.0× 5.0	1.0	34.0
		7	14.0× 8.0	—	*
		21	10.0× 2.0	—	*
30	90	0	16.0× 6.0	1.8	40.0
		7	18.0×11.0	—	37.0
		21	10.0× 4.0	—	25.0
90	15	0	34.0× 9.0	3.0	45.0
		7	27.0×10.0	—	32.0
		21	26.0×11.0	—	35.0
90	30	0	36.0×11.0	3.0	36.0
		7	38.0×13.0	—	38.0
		21	22.0×12.0	—	22.0

* Unmeasured because puncture point on the liver surface could not be detectable.

was carried out on 44 patients with liver diseases. Ultrasonically guided liver biopsy and liver biopsy under laparoscopic control were performed according to the procedures already described in detail[2,6,13,14] and outlined in Figure 4 (A–D). The linear electronic real-time ultrasound scanner used (for the former biopsy only) was a Toshiba SAL-50A and the puncture transducer used was a Toshiba GCB-306M. Siverman needle or Tru-Cut needle of 13 gauge or 16 gauge was served as a biopsy needle.

Percutaneous microwave coagulation combined with ultrasonically guided liver biopsy was carried out by the following method: After the biopsy procedure was over, the needle-electrode was placed into the outer tube of Siverman needle and its tip was forced to reach the base of the needle tract in the liver. The tissue surrounding the antenna was coagulated by microwave irradiation (30–60 watts, 15–30 sec) (Figure 4-E, F). When a deep layer biopsy was done, coagulation up to the liver surface had to be done step by step, while the needle-electrode coupled with Siverman needle was being gradually withdrawn through the needle tract (Figure 4-G). After this coagulation process, the needle-electrode and Siverman needle were completely withdrawn from the liver (Figure 4-H). The coagulated area could be seen ultrasonographically.

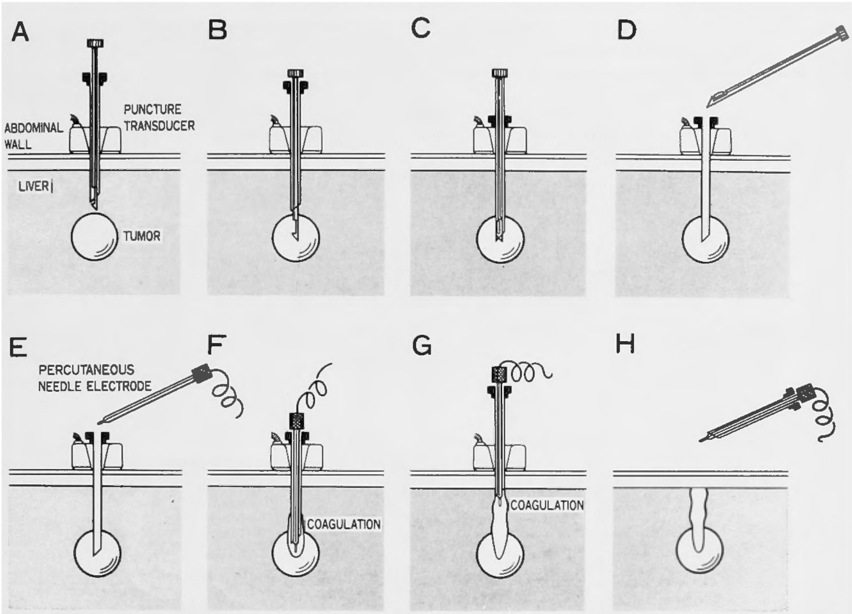

Figure 4. Illustration of the technique of percutaneous microwave coagulation (E–H) combined with ultrasonically guided liver biopsy (A–D).

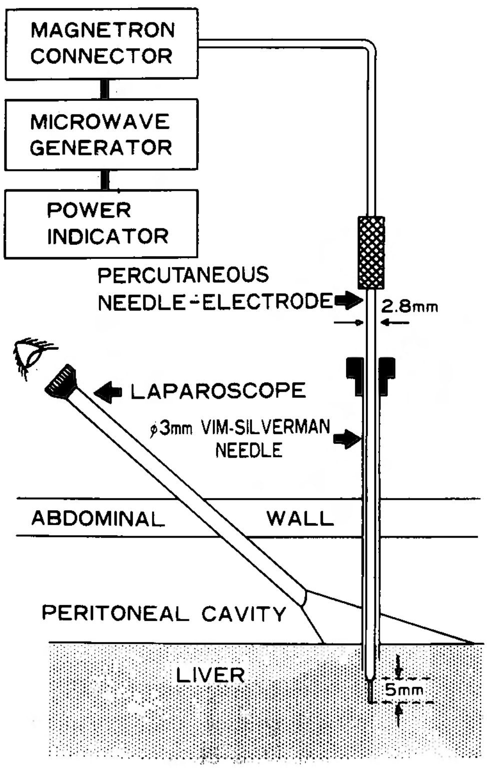

Figure 5. Illustration of the technique of percutaneous microwave coagulation combined with laparoscopic liver biopsy.

Table 2. Cases of percutaneous microwave coagulation combined with ultrasonically guided liver biopsy and laparoscopic liver biopsy.

Disease	No. of Patient
Ultrasonically guided liver biopsy	
Hepatocellular carcinoma	13
Cholangiocellular carcinoma	2
Metastatic carcinoma	1
Hemangioma	5
Focal fatty infiltration	2
Granuloma	1
Focal nodular hyperplasia (suspect)	1
Cirrhosis	1
Chronic hepatitis	1
Total	27
Laparoscopic liver biopsy	
Hepatocellular carcinoma	3
Metastatic carcinoma	1
Cirrhosis	5
Hepatitis	6
Banti's syndrome	1
Liver cyst	1
Total	17

About 30 seconds of galvanization (direct current) was useful for dissociating the needle from the coagulated tissue and keeping it from being torn off during the electrode withdrawal.

The procedure for microwave coagulation combined with laparoscopically controlled liver biopsy was almost the same as that described above (Figure 5).

Of the 44 cases studied, 27 cases were subjected to ultrasonically guided liver biopsy and 17 to laparoscopically controled liver biopsy (Table 2).

Results

Findings in animals

Tissue around the antenna of the needle-electrode was coagulated in teardrop shape by microwave coagulation, so that a spindle-formed coagulated area could be seen on the cut surface along the needle tract. Table 1 shows the measurements of the areas coagulated under different conditions. The width of coagulation, determined in the direction perpendicular to the needle tract, was maximal at the base of the antenna. A deeper layer than the tip of the antenna was not almost coagulated (Figure 3).

In the specimen obtained on day 0, a discolored band of 1–3 mm in width surrounding the coagulated area was found macroscopically. Histological examination showed that the discoloration was due to congestion. Such a discolored band was unseen in the specimens obtained on day 7 and day 21. Instead, a thin fibrotic layer was recognized between the coagulated area and the intact tissue in these specimens.

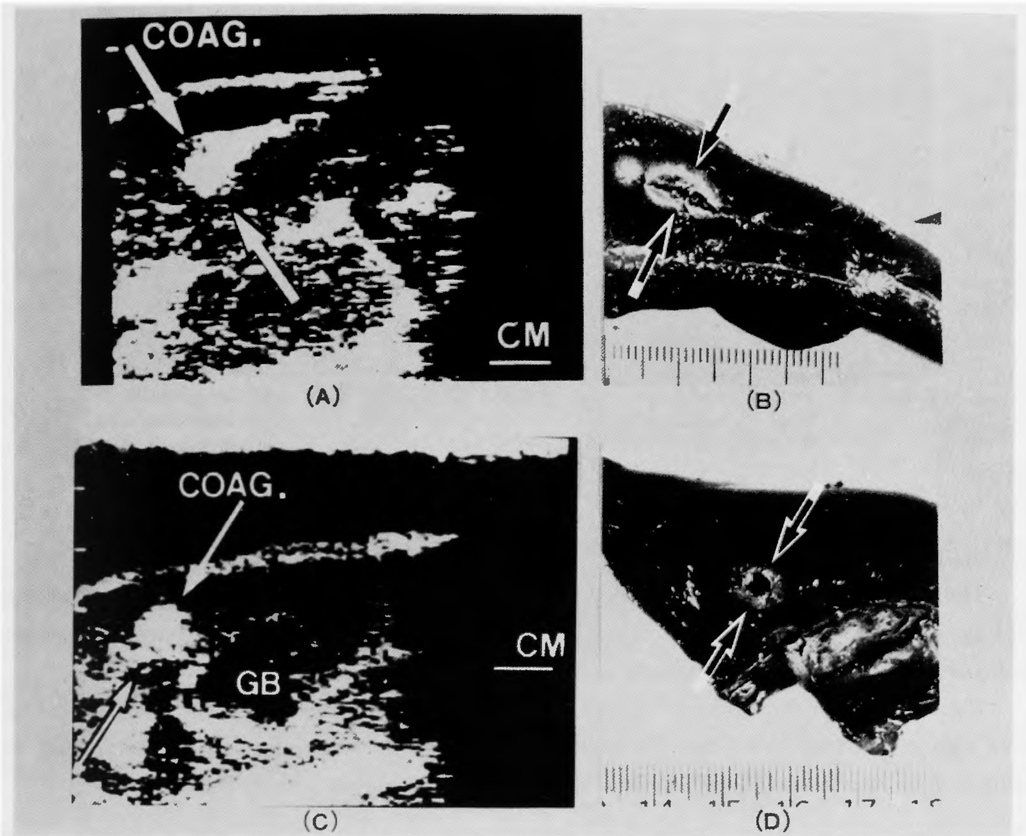

Figure 6. Ultrasonography monitored during and after microwave coagulation (A, C) and view of cut surface of the coagulated area in the removed liver (B, D). A and B: View of the section along the needle-electrode. C and D: View of the section in the direction perpendicular to the needle-electrode. Hyperechoic are (white arrow) is identical macroscopically in shape and range of the coagulated area (black arrow).

Ultrasonographic monitoring revealed a hyperechoic change around the antenna of the needle-electrode during and after coagulation. The hyperechoic area was identical in shape and range with the coagulated area macroscopically observed in the removed liver specimen (Figure 6).

Clinical findings

Ultrasonically guided liver biopsy was successful with the assistance of percutaneous microwave coagulation in all the 26 cases (Table 2). In several cases we experienced mild bleeding or blood oozing after biopsy. But microwave coagulation exerted a perfect hemostatic effect in these cases. Histological confirmation of the diagnosis was established in all the cases except three cases. One case of hepatocellular carcinoma and two cases of hemangioma, which have been diagnosed by ultrasonography and angiography, failed to be diagnosed histologically because of insufficient biopsy specimens.

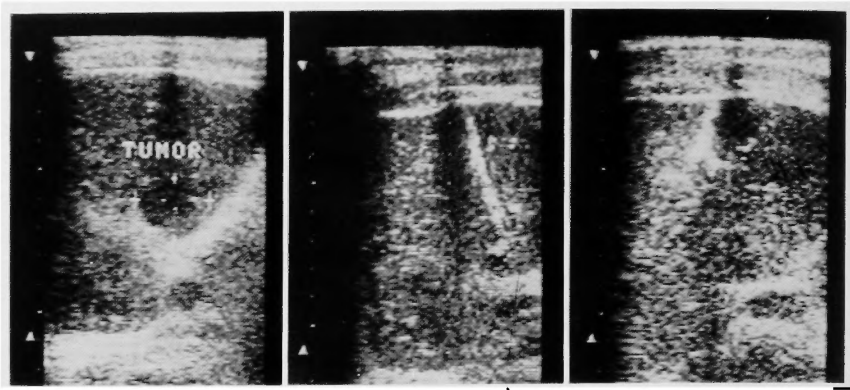

Figure 7. Percutaneous microwave coagulation combined with ultrasonically guided liver biopsy in a patient with hepatocellular carcinoma. A: Right intercostal scan before puncture. A small 2.7×2.6-cm tumor is seen. B: Ultrasonograph after biopsy of the tumor and microwave coagulation through the needle tract Hyperechoic change is seen. C: Ultrasonograph after biopsy of liver parenchyma to diagnose the severity of chronic hepatitis and microwave coagulation.

The hyperechoic change was observed ultrasonographically (Figure 7). The macroscopic findings on the cut surface of the liver resected after coagulation from the same patient are shown in Figure 8. The discolored area was the coagulated area around the needle tract.

The results of percutaneous microwave coagulation combined with laparoscopic liver biopsy were also satisfactory in all the 17 cases. The hemostatic effect of this procedure could be confirmed by laparoscopy. Histological diagnosis was established in all the cases.

Complications

A transient discomfort and a pain in the right hypochondrial region lasting for a few hours during and after the procedure were common complaints. However, these symptoms were mild in most cases and only a few cases required a small intravenous dose of diazepam, which brought about satisfactory therapeutic benefits. A severe and persistent pain was not experienced. Any fever was not induced by the procedure.

Eight of the 44 patients were treated surgically one to three weeks after liver biopsy. Laparotomy disclosed none of hematoma, abscess, and bile leakage. All of them were operated on for malignant disease, but careful follow-up gave no evidence of malignant seeding in the needle tract or the peritoneal cavity. Thirty-six patients who did not undergo surgery were also carefully followed up. A decrease of hematocrit, leucocytosis, or an increase of serum transaminase were not demonstrated in any of them.

Discussion

Liver biopsy under visual control in conjunction with laparoscopy[6,11] and ultrasonically guided liver biopsy[4,13,14] have recently been widely carried out to make a histological diagnosis in the liver disease as well as endoscopic biopsy in the alimentary tract disease. However, there

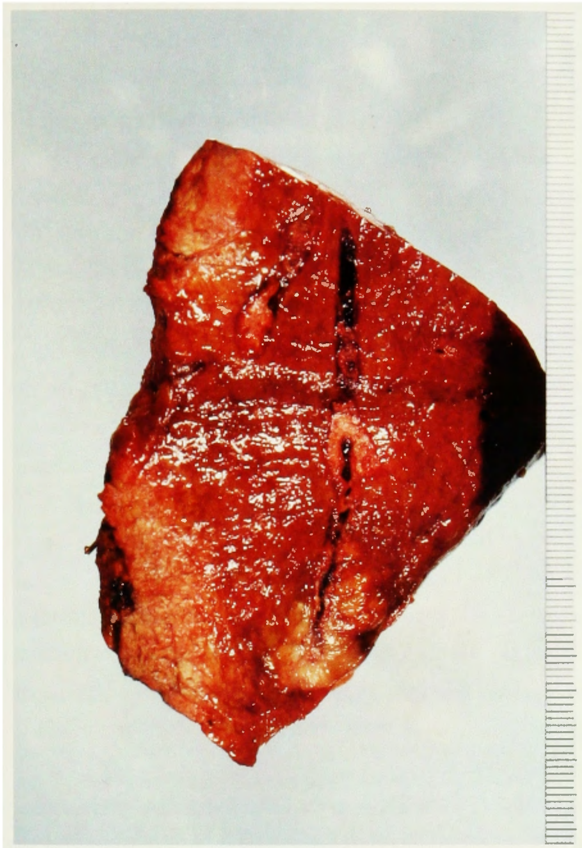

Figure 8. Macroscopic findings on the cut surface of the resected liver from the patient presented in Figure 7. Discolored area showing the coagulated area around the needle tract.

are as yet several unsolved problems, such as hemorrhage, bile leakage, malignant seeding in the needle tract etc. resulting from needle biopsy[2,4,9]. Liver biopsy is thought to be contraindicated for patients with hemorrhagic diathesis.

Hemostatic agents, such as oxidized cellulose and thrombin, may be used as a preventive measure against bleeding[1,8]. The availability of fine needle aspiration biopsy under ultrasound guidance, especially real-time ultrasound guidance, has been established. It is a simple and reliable method, virtually free of complications. It may be used primarily for the patient with focal liver diseases[3,10]. Aspiration biopsy, however, offers some problems. Ohto[13] reported that in two of 19 patients with hepatocellular carcinoma, no malignancy was detected by this method because of cirrhosis and difficulty in cytological differentiation, and he concluded that aspiration biopsy still has some inherent limitations as a modality for cytological diagnosis. Therefore, tissue biopsy seems essential for examination of at least a part of focal liver disease cases not to mention diffuse liver disease cases.

The risk factor responsible for malignant seeding in the needle tract following biopsy is difficult to assess. Malignant seeding in the needle tract subsequent to needle biopsy or fine needle aspiration biopsy has been reported, if not frequently[7,9].

In an attempt to solve these problems, we devised a new method named "percutaneous microwave tissue coagulation", a combination of microwave surgery and liver biopsy. The tissue coagulator which is instrumental to this microwave surgery was originally intended for use in hepatectomy. Since the performance of the microwave tissue coagulator in hemostasis and tissue coagulation has been so striking that it is nowadays utilized not only for liver surgery but also for partial splenectomy[3,20], tumor reduction therapy of unresectable malignancies[16], endoscopic surgery and so on.

The contrivance we made this time was to work out a special device that suits percutaneous microwave coagulation combined with liver biopsy. Consequently, we devised a fine needle-like coaxial cable with a microwave antenna, which we named "percutaneous needle-electrode" (needle-electrode). In our clinical study, done under real-time ultrasonic guidance, puncture of large vessels could be avoided and massive bleeding was never seen, except that a few patients experienced mild bleeding or blood oozing. It goes without saying that microwave coagulation exerted a perfect hemostatic effect in these cases. Hematoma, bile leakage, or malignant seeding in the needle tract was not demonstrated in any of the patients operated on after this procedure. Although we obtained no positive evidence substantiating more definitely the effectiveness of microwave coagulation against malignant seeding, it does not seem unrealistic to presume that damaged tumor tissue and malignant cells which were probably in the needle tract must have been necrotized during the procedure.

Aside from the above data, we wish to stress the following points supporting its high safety: 1) Tissue is coagulated in teardrop shape and a deeper layer than the tip of the antenna is not coagulated, which suggest that the range of coagulation is rather limited. 2) The coagulating operation can be monitored ultrasonographically and the coagulated area can be visualized as a hyperechoic area.

If the needle-electrode and the coagulating technique are further improved, small liver tumors less than 2–3 cm in diameter may be completely necrotized by several times of the coagulation procedure. NOGUCHI[12] presented experimental data attesting that microwave coagulation elicited an immunological antitumor effect. Likewise, YAMAUE[23] showed that in experimental animals the incidence of metastases was suppressed and anti-tumor immunity against implanted primary malignancies was augmented by microwave coagulation therapy. Naturally, our future investigative efforts will be directed towards developing an innovative, non-invasive technique that assures us of excellent performance in the curative treatment of small liver tumors.

Summary

For the prevention of hemorrhage and malignant seeding in the needle tract after liver biopsy, we applied our microwave tissue coagulator in liver biopsy. A specially designed microwave needle-electrode, that permits percutaneous microwave coagulation through the

biopsy needle, was devised. In the experimental study which was undertaken to gain a clear picture of the needle-electrode, three dogs were used. By microwave coagulation, the liver around the antenna attached to the tip of the needle-electrode was coagulated in teardrop shape. Ultrasonographic monitoring revealed a hyperechoic change around the antenna during and after coagulation. The hyperechoic area was almost identical in shape and range with the coagulated area macroscopically observed in the removed liver specimen. At the clinical level a combination of percutaneous microwave coagulation and liver biopsy was carried out on 44 patients with liver diseases. Of the 44 cases studied, 27 cases were subjected to ultrasonically guided liver biopsy, and 17 to laparoscopic liver biopsy. Microwave coagulation exerted a perfect hemostatic effect in all the cases. Eight cases of 44 patients were operated on for malignant disease one to three weeks after liver biopsy. Laparotomy disclosed none of hematoma, abscess, bile leakage and dissemination of carcinoma cells. Careful examination of the resected liver gave no evidence of malignant seeding and hematoma in the needle tract. Thirty-six patients who were not operated were also carefully followed up, and no complications were revealed.

In conclusion, our microwave tissue coagulator can be used easily and safely in liver biopsy for the prevention of hemorrhage and malignant seeding in the needle tract.

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和文抄録

肝生検における経皮経肝的マイクロ波凝固法 基礎的，臨床的研究

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長崎 靖彦

マイクロ波凝固法は組織の凝固，止血にすぐれているため，本法を肝生検に伴なう出血，腫瘍細胞翻種の防止に応用した．

生検針の外筒を介して経皮的にマイクロ波凝固ができるよう特別に電極を作成し，動物実験にてその安全性と有効性を確認した．

臨床的には44例の肝疾患を有する症例の肝生検において本法を応用し，合併症もなく，完璧な止血効果が得られた．生検に伴ない，かりに腫瘍細胞が穿刺ルートに翻種されたとしても，マイクロ波凝固により凝固壊死に陥いるものと考えられる．